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Lack of Effect of Combined Low Intensity Laser Therapy/Phototherapy (CLILT) on Delayed Onset Muscle Soreness in Humans

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***Background and Objectives*: This study, which was approved by the University's Ethical committee, was conducted to investigate the effectiveness of Combined Low Intensity Laser Therapy/Phototherapy (CLILT) in alleviating the signs and symptoms of Delayed Onset Muscle Soreness (DOMS) over an 11-day period.**

***Study Design/Materials and Methods*: Thirty-six subjects (18 M: 18 F) were randomly allocated, under strictly controlled double-blind conditions, to one of three experimental conditions: Control, Placebo, and CLILT (660–950 nm; 11 J/cm^2; pulsed at 73 Hz). DOMS was induced in a standardised fashion in the non-dominant elbow flexors using repeated eccentric contractions until exhaustion was reached. Subjects returned on five consecutive days, and two days during the following week, for treatment according to group, and assessment of outcome variables including range of motion, pain, and tenderness.**

***Results*: While analysis of results using repeated measures and one factor ANOVA with post-hoc tests showed significant changes in all variables over time ($P < 0.05$) as a result of the induction procedure, there were no significant differences observed between groups.**

***Conclusions*: CLILT failed to show any beneficial treatment effect on DOMS, at least at the parameters used here. These results therefore provide no evidence for the claimed biostimulating effects of such therapy. Lasers Surg. Med. 24:223–230, 1999.**

Key words: combined phototherapy/laser therapy; eccentric exercise; muscle damage

INTRODUCTION

Delayed onset muscle soreness (DOMS) has been described by numerous authors as the sensation of pain experienced 8–72 hours following exercise, peaking between 24 and 48 hours and lasting some 5–10 days post-induction [1–4]. This myogenic phenomenon has been particularly associated with eccentric contractions [5]; however, it can be produced by any activity in which the muscles produce higher forces than usual or sustain forces for longer durations than usual [6]. The cardinal signs and symptoms of DOMS are: loss of range of movement (due to muscle shortening or pain), swelling, decreased muscular per-

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formance and pain, which becomes particularly apparent during movement or palpation. A large volume of research has been undertaken to identify the underlying pathophysiology of DOMS [7–9]; despite this, four main theories still remain which have yet to be definitively proven or disproven: the torn-tissue theory [10], the connective tissue damage theory [11], the muscle spasm theory [12], and the inflammation theory [9].

What has been generally accepted (and widely documented) is the nature of the damage to the affected muscle fibres, and the associated (external) changes that can be observed and measured. Newham et al. [13] found the presence of focal changes in eccentrically exercised muscles; in contrast there was an absence of such changes in muscles that had been concentrically exercised. The number of affected fibres increased over the following 30 hours, without further exercise, with reports of "extensive to very extensive changes" occurring. Friden et al. [14,15] demonstrated the extent of such damage within the muscle fibres by identifying the streaming and disruption of Z-bands (i.e., the array of the digitations of interconnecting thin and thick myofilaments). They further reported that such Z-band disruption may lead to a release of protein bound ions, resulting in an increase in oedema and subsequent activation of nociceptors, thereby causing pain. Whereas increases in swelling were considered by some to contribute to the pain associated with DOMS [11,16,17], other authors have found no correlation between swelling and pain [2,18].

In contrast to the above, there has been relatively little research completed on the management of DOMS. A small number of studies have examined the effect of a variety of anti-inflammatory agents [19–22], oral analgesics [23], and vitamin supplements [24–26]. These studies have yielded conflicting and confusing results. Physical modalities that have been assessed include ice massage [27] and manipulation [28]. A variety of electrotherapeutic modalities have also been examined in an attempt to identify an efficacious treatment for DOMS (Transcutaneous Electrical Nerve Stimulation [4,29]; Pulsed Ultrasound [30,31]; Combined Low Intensity Laser Therapy/Phototherapy [32]). Similarly, results from these studies have failed to identify an effective management regime for this condition.

Low intensity laser therapy and combined laser therapy/monochromatic light (CLILT) have been promoted as effective in the treatment of a myriad of conditions, based upon putative effects which include acceleration of wound healing and the relief of pain [33]. Despite this, the underlying mechanism of action of CLILT remains unclear and the clinical efficacy of this modality has still to be definitively established. Thus, further investigation of this modality appear to be warranted. Previous work at this centre has included the assessment of claimed hypo-algesic effects of CLILT using experimentally induced ischaemic pain [33–36] and (more recently) delayed onset muscle soreness [32] with variable results. In this latter preliminary study, application of CLILT at 73 Hz for 12 minutes (660–950 nm; 31.7 J/cm^2) over a 3-day period to exercise-damaged muscles showed no significant effect upon range of movement, pain, or tenderness measures. However, an interesting trend was apparent, in that tenderness measures in the CLILT group remained higher than either Control or Placebo on the (final) third day post-exercise. Given these results, and the duration of DOMS subsequent to induction lasting for some 10 days, it was decided to evaluate the effectiveness of CLILT over this extended period.

It was postulated from these preliminary findings that assessment of the effects of CLILT on DOMS over an extended period of time might confirm whether the previously observed increase in tenderness represented an acceleration in the healing process, or indeed just an exacerbation of the symptoms. The aim of the current study therefore was to determine the effects of CLILT on the pain and dysfunction associated with DOMS over an 11-day period.

MATERIALS AND METHODS

Recruitment and Induction

After ethical permission was obtained from the University's Research Ethics committee, healthy human volunteers (n = 36; 18 M:18 F; age 19–25 years) were recruited and screened for relevant pathologies including cardiovascular problems, current trauma or pain, neuropathy, and current or recent courses of analgesics or steroids. Regular weight trainers were excluded, as were subjects with diabetes mellitus.

Before beginning the experiment, subjects received verbal and written instructions explaining the induction procedure and the fact that CLILT may or may not be applied. All subjects signed a consent form and were specifically reminded of their right to withdraw from the study at any time.

General Overview

Each subject attended for a total of seven sessions over an 11-day period; i.e., Monday to Friday of the first week, as well as Monday and Thursday of the following week. The initial session lasted approximately 40 minutes and the remaining sessions lasted some 30 minutes each. The procedure for day 1 differed from remaining days simply in that subjects underwent DOMS induction on the first day, in addition to the daily routine of measurement and treatment. On this first attendance, subjects had initial (baseline) measurements of range of movement and mechanical pain threshold taken prior to any exercise. Immediately following the exercise protocol, an initial assessment of subjective pain was completed using a computerised visual analogue scale (VAS) and subjects were treated, under double-blind conditions, according to randomised group allocation; all variables were measured post-treatment/control. On remaining days, the same pre- and post-treatment measurement regime was followed for all variables; additionally, at the end of days 1 and 3 (i.e., the time of peak pain from the induction procedure and DOMS respectively), subjects completed a short form McGill pain questionnaire to assess the greatest level of pain experienced at that time.

Pain Induction

DOMS was induced in a standardised fashion in the non-dominant elbow flexors with subjects seated behind a "preacher's bench". The maximum weight lifted with one voluntary concentric contraction (1 Repetition Maximum or 1 RM) was assessed for each subject, using free weights (i.e., a loaded dumbbell). After this, the subject was allowed a thirty second rest. This weight was then used to eccentrically exhaust the elbow flexors through repeated eccentric lowering of the weights, under control, through their entire available range. This process was repeated until the subject could no longer control the speed of descent of the weights. A further 30 second rest was given followed by a second bout of exercise, again to exhaustion. A second rest period was followed by the third (and final) period of exhaustive exercise.

MEASUREMENTS

Range of Movement

Measurements of range of elbow flexion, extension, and resting angles were performed using a universal goniometer with subjects standing. The lines of the humerus and radius were used as standardisation points with the lateral epicondyle of the humerus acting as the axis of movement. For all measurements, 180° of extension was taken as the zero position; hence all flexed measurements were expressed as positive values and hyper-extension measurements as negative values. The ranges measured for the purposes of the current study were:

1) Extension angle (EANG): This was taken as the maximum available range as the elbow was fully straightened;
2) Flexion angle (FANG): This was taken as the maximum available angle of flexion when the hand was brought up to the shoulder; and
3) Angle at rest (RANG): This was taken as the angle of flexion made at the elbow as the arm hung loosely by the side.

Mechanical Pain Threshold/Tenderness

Mechanical Pain Threshold (MPT) was measured using a pressure algometer capable of measuring a compressive force of up to 100 N through a 1-cm diameter head (Electronic Force Gauge, Salter, West Bromwich, England). MPT was used as a correlate of tenderness and measured at eight points at 4-cm intervals along the median line of the biceps brachii from the radial insertion to the bicipital groove. In keeping with our previous studies, an upper limit for MPT was set at 40 N [4].

Measurement of Subjective Pain

Subjective pain was assessed using both computerised Visual Analogue Scale (VAS) and McGill Pain Questionnaires (MPQ). Following DOMS induction on day 1, each subject was asked to rate their current level of pain by marking a computerised VAS. For this a 10-cm line appeared on a computer screen with "No Pain" marked at one end and "Maximum Pain" marked at the other. Subjects were asked to move a mouse-controlled pointer along the line to indicate their current level of pain. A total of four scales appeared at 30-second intervals on each occasion, in a random orientation and position, on the computer monitor; the average of these was taken as the best estimate of current pain. This procedure was repeated before and after treatment on each subsequent day.

On days 1 and 3, each subject was asked to

complete a short form McGill pain questionnaire [37], which provided a quantitative and qualitative measure of the "worst pain" experienced by each subject during the pain induction procedure, and at what might be expected to be the most painful time (i.e., 48 hours after pain induction).

Experimental Groups

Each subject was randomly allocated, under strictly controlled double-blind conditions, to one of three experimental groups: Control, Placebo, and Combined Low Intensity Laser Therapy/Phototherapy (CLILT). Regardless of group allocation, all subjects received instruction and warning about CLILT prior to treatment, which was performed on each day as defined below:

1) Control group: Subjects received 4 minutes rest in a supine position with the forearm resting comfortably across the chest;
2) CLILT group: Subjects rested supine on a plinth, their eyes shielded by protective goggles, and received 4 minutes of irradiation using a GaAlAs cluster head multi-diode array (660–950nm; maximum output 534 mW; 11 J/cm^2; pulsed at 73 Hz for 4 minutes) powered by a base unit (2001 unit, Omega Laser Systems, London). The area irradiated was standardised as the site over the distal half of the biceps brachii, corresponding to the musculotendinous junction of the affected muscles. The treatment head and base unit were shielded by towels to enhance the blinding procedure; and
3) Placebo group: Subjects in this group were treated in an identical fashion to those in the active treatment group except that they received 4 minutes of sham irradiation using a dummy cluster head positioned as before.

Data Analysis

Data was collected and transferred to analysis sheets for analysis by variable. Repeated measures and one factor ANOVA, with post-hoc Scheffe-F tests, were carried out to determine if there were any differences between groups or over time. Such analysis was performed on data standardised for each subject using "baseline difference" scores (i.e., differences from the initial pre-exercise scores) to allow for variation between subjects, and to assess treatment effects over the duration of the study. The only exception to this were MPQ and VAS data, which were analysed as raw (i.e., no difference) scores.

RESULTS

General

Results for all variables are presented in Figure 1 (range of movement), Figure 2 (mechanical pain threshold/tenderness, visual analogue scale), and Figure 3 (McGill pain questionnaire); all graphs show means ± SEM of the baseline difference scores with the exception of VAS scores, which are similarly presented as means ± SEM of the raw data, and MPQ scores, which are presented as PRI values from days 1 and 3. In common with previous studies at this centre [4,18,32], results from the current study demonstrated the commonly accepted changes associated with DOMS during the acute stage, i.e., loss of range of movement, increase in tenderness and subjective pain.

Range of Movement

Range of movement results are shown in Figure 1; range of extension (EANG) in the upper graph; flexion (FANG) in the middle graph; and resting angle (RANG) in the lower graph. For all graphs, negative values represent a worsening of the condition, (or more specifically a loss of the available range), and positive values represent an improvement in the condition.

As can be clearly seen from the upper graph, subjects in all groups lost the ability to fully straighten their arm over the initial four days of the trial, with a gradual improvement in achievable range from day 5 onward. This loss of EANG was significant ($P = 0.0001$) over time; however no significant differences were seen between groups.

The middle graph clearly shows that subjects in all groups lost some degree of flexion following exercise, with this loss not improving until day 5. While the loss of FANG proved to be significant over time ($P = 0.0001$), there were no significant differences seen between groups.

Results for RANG can be seen in the lower graph of Figure 1. Subjects in all groups experienced an increase in elbow resting angle during the initial four days of the study, with RANG gradually improving over the following seven days. Statistical analysis of results showed this change in RANG to be significant ($P = 0.0001$)

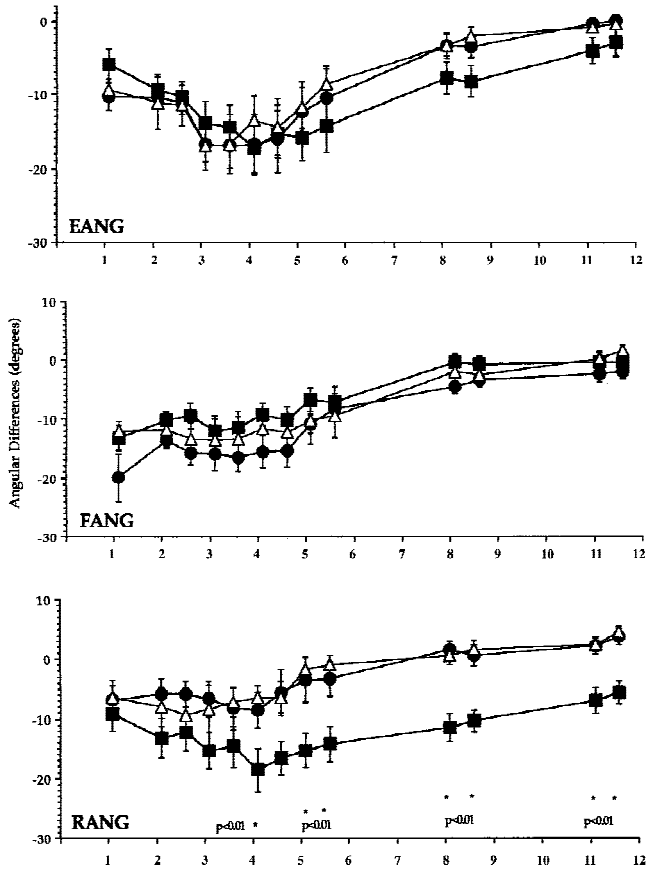

Fig. 1. Range of movement differences (means ± SEM): EANG (upper); FANG (middle); RANG (lower). Control (n), Placebo (D), 73Hz (l), Positive values represent an improvement and negative values represent a worsening in range of movement. Labels on the X-axis correspond to measurement days.

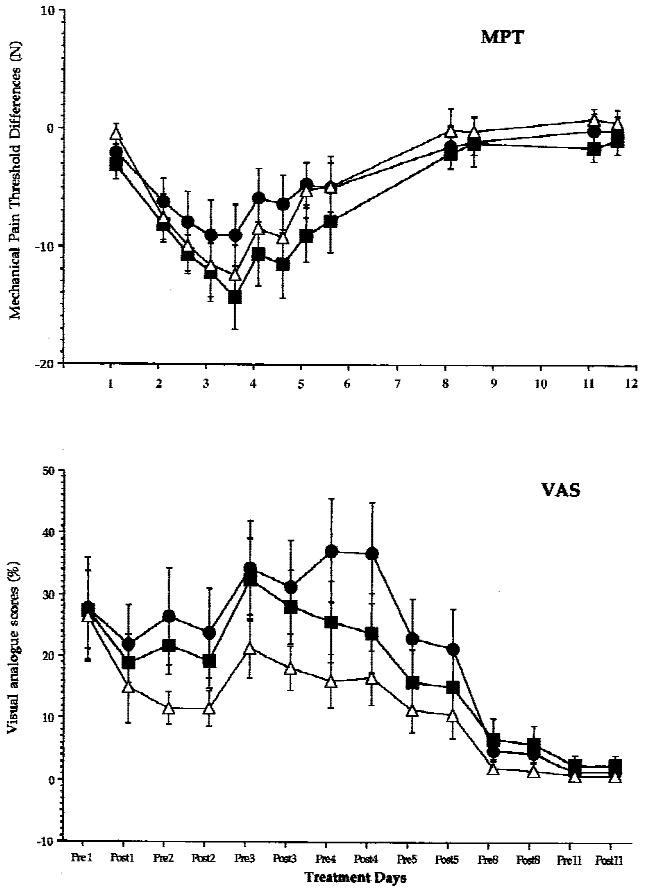

Fig. 2. Pain assessment (means ± SEM): MPT (upper: difference scores); VAS (lower: raw scores). Control (n), Placebo (D), 73Hz (l). Positive values in the upper graph reflect increases in pain while negative values in the lower graph reflect increases in tenderness. Labels on the X-axis correspond to measurement times.

over time and between groups; subsequent post-hoc tests showed significant differences between the Control group and both Placebo and CLILT groups during the latter half of the experiment. Indeed (and in contrast to the other groups) the Control group did not regain pre-exercise RANG values by the end of the trial.

Mechanical Pain Threshold/Tenderness

Results for mechanical pain threshold for the lower four measurement points are shown in Figure 2 (upper graph). Again results are plotted as baseline difference scores with negative values correlating with a decrease in mechanical pain threshold (or an increase in tenderness). As can be seen, subjects in all groups experienced immediate decreases in mechanical pain threshold following pain induction, which continued until post-treatment on day 3. From day 4 onward mechanical pain threshold increased until pre-induction values were regained by the end of the study. Statistical analysis of results showed significant ($P = 0.0001$) decreases in mechanical pain threshold over time; however no differences were found between groups.

Visual Analogue Scale (VAS)

Results for subjective pain assessment using the VAS are summarised as raw values in Figure 2 (lower graph). In the graph positive values represent an increase in subjective pain (i.e., hyperalgesia) and negative values represent an hypoalgesic effect. As can be seen, pain levels increased slowly following DOMS induction, peaking on day 3 for Control and Placebo groups and day 4 for the CLILT group. Both Control and Placebo groups then displayed a gradual decrease in pain from day 3 onward, while the CLILT group continued

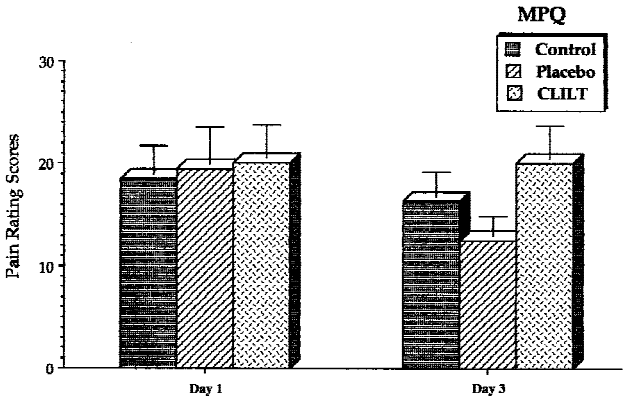

Fig. 3. McGill pain questionnaire (PRI) scores (means ± SEM). Positive values correspond to an increase in pain.

to experience pain for a further 24 hours prior to pain subsiding. From day 5 onward the pain experienced by the CLILT group decreased, with all groups returning to near-baseline levels by day 8 (i.e., the following Monday). Statistical analysis of results showed significant differences in pain over time ($P = 0.0001$), however there were no significant differences observed between groups.

McGill Pain Questionnaire (MPQ)

Results of the Pain Rating Index (PRI) calculated from completed questionnaires from both days 1 and 3 are presented in Figure 3. Again statistical analysis did not show any significant differences between groups for either day or for any of the subsections of the questionnaire, although on day 3, subjects receiving active treatment reported an increase in pain (i.e., a higher PRI) when compared to either Control or Placebo.

Summary

These results clearly showed an increase in subjective pain and tenderness, together with a loss of available range of movement; however, no consistent statistically significant differences were seen between groups. Isolated marginally significant differences were seen in the results for RANG, with the Control group maintaining higher RANG values than either Placebo or CLILT during the latter half of the study.

DISCUSSION

This study aimed to assess the effect of combined low intensity laser therapy/ phototherapy (CLILT) on DOMS, as an extension to previous work carried out at this centre [32]. In that previous preliminary study, we assessed the effects of CLILT during the initial 3 days of the DOMS process and found no significant results, but rather an apparent trend towards a treatment-mediated prolonging of the tenderness associated with this condition. The current study assessed the effects of CLILT on DOMS over an 11-day period and found that such combined therapy provided no consistent, statistically significant effect when compared to either Control or Placebo groups for any of the variables measured, at least at the parameters used here.

In general, the nature and degree of the symptoms of DOMS experienced in this study were consistent with previous studies both at this centre and others [4, 22]. All subjects experienced a loss of available range of movement, which was most noticeable between 48–72 hours. In an earlier study, Friden et al. [14] attributed this loss of range to some form of distortion of the contractile apparatus of the muscle, whereas Howell et al. [17] suggested that swelling in the region of the musculotendinous junction affected the muscle's ability to move the limb through full range.

Tenderness and pain levels showed similar changes over time, with maximal discomfort experienced in the 24–48-hour period. Results from the current study agree with several authors who found peak pain levels associated with the region of the musculotendinous junction [2,6,16]. This discomfort remained for some 5–7 days post-exercise, albeit decreasing in intensity from day 4 onward. One author suggested that this increase in tenderness was a consequence of connective tissue damage, which may have altered the sensitivity of muscle receptors [38]; thus stimuli which previously would have been considered as subthreshold may have later been interpreted as pressure and ultimately described as pain.

From the results of subjective pain, as measured by the VAS, both Control and Placebo groups followed an expected pattern, with peak soreness being reported between 24–48 hours post-DOMS induction. These groups then showed a gradual improvement in symptoms over the following days. The CLILT treatment group however followed a slightly altered time course. Subjects in this group reported a peak soreness occurring on day 4, (i.e., between 48–72 hours). It appears from the results that, although not significant, the CLILT treatment group suffered from a slightly greater degree of pain (and for a marginally longer duration) than either Control or Placebo groups. Further analysis of the result

from the McGill pain questionnaire completed on day 3 suggested that subjects in the CLILT group did indeed experience more pain than their counterparts in the other groups, at least at this time point; again (however) it must be stressed that these results did not reach statistical significance. This apparent treatment-mediated prolonging of pain corresponds to our previously reported laser-mediated increases in tenderness [32]. On the basis of these latter findings, we had speculated that CLILT may have accelerated the inflammatory response associated with DOMS, and subsequently shortened the overall duration of symptoms. Results from the current study, however, suggest that the inflammatory response was not accelerated but rather, if anything, such treatment may indeed have been pro-inflammatory with the symptoms being prolonged over a further 24-hour period.

Laser therapy and combined CLILT therapy have become popular modalities for the treatment of a variety of conditions in a number of countries [40]. However, despite such apparent popularity, scepticism remains, not least because of the lack of an obvious mechanism(s) of action and the use of a variety of irradiation parameters in published studies [33]. In the current study, CLILT was investigated given its popularity among clinicians and apparent suitability for irradiating a comparatively large tissue area (i.e., the affected muscles). Our previous study had additionally also suggested an apparent (although not significant) pro-inflammatory effect of the therapy in a preliminary investigation over a 3-day period [32]. The current results convincingly demonstrate the lack of any therapeutic effect of this modality upon DOMS and (by implication) in muscle damage and acute myogenic pain, at least at the parameters used here. This notwithstanding, while the precise effects of irradiation parameter manipulation remain unknown, the generalisability of these findings in terms of the putative benefits of other treatment regimes remains occult.

CONCLUSIONS

What is clear from the results of the current study is that repeated eccentric exercise produces the symptoms of delayed onset muscle soreness in untrained individuals. Combined phototherapy/low intensity laser therapy when applied, at the parameters used here, appear to have little beneficial effect in reducing these symptoms. Therefore the authors can find no evidence to support the use of CLILT in the treatment of delayed onset muscle soreness.

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